✌ ♌ ♍ ♎

Project Status Report for: April 2001

Project Title: Ultra Low NOx Integrated System for Coal-Fired Power Plants

Project Number: 91890460 **Project Manager:** John Marion

Customer Name: U.S. DOE / Performance Projects **Project Leader:** Charles Maney

GOALS AND OBJECTIVES:

Develop low cost, retrofit NO_x control technologies to address current and anticipated, near term emissions control legislation for existing coal fired utility boilers. Specific goals include:

- Achieve < 0.15 lb/MMBtu NO_x for eastern bituminous coals
- Achieve < 0.10 lb/MMBtu NO_x for western sub-bituminous or lignitic coals
- Achieve economics at least 25% less than SCR-only technology
- Validate NOx control technology through large (15 MWt) pilot scale demonstration
- Evaluate the engineering feasibility and economics for representative plant cases
- Provide input to develop commercial guidelines for specified equipment
- Provide input to develop a commercialization plan for the resultant technologies

WORK PLANNED FROM PREVIOUS REPORT:

Task 2.4 – Advanced Control System Design

- Resolve accuracy of coal mass flow meters and determine methodology for testing of coal flow balancing in the BSF.

Task 3.1 – Test Planning & Facility Preparation

- Complete preparations for week 2 BSF testing.

Task 3.3 – Combustion Testing and Cleanup

- Complete the second combustion test period in the BSF.

ACCOMPLISHMENTS FOR REPORTING PERIOD:

The second combustion test period in the BSF was executed 4-30-01 through 5-5-01. During this testing two coals were fired in the BSF, a subbituminous coal from the Powder River Basin (Cordero Rojo Complex Coal, Kennecott Energy) and a high volatile bituminous coal from Southern Indiana. Initial results from the testing indicate a baseline (re. unstaged / post-NSPS type) NOx emission level of approximately 0.50 lb/MMBtu for the subbituminous coal and 0.60 lb/MMBtu for the bituminous coal. NOx emissions values significantly below the test objectives of 0.10 lb/MMBtu for the subbituminous coal and 0.15 lb/MMBtu for the bituminous coal were achieved during the testing with low levels of CO and unburned carbon. Additional information on the second week of combustion testing will be presented in the section on Task 3.3 – Combustion Testing and Cleanup.

Task 2.4 – Advanced Control System Design

- *Resolve accuracy of coal mass flow meters and determine methodology for testing of coal flow balancing in the BSF.*

A set of 12, ABB Kent-Taylor mass flow meters was used in last fall's BSF testing to measure, and allow for control over, the coal flow rate to each of the facilities 12 coal nozzles (3 elevations x 4 corners). Results from this work suggested little to no change in combustion performance for the subject medium volatile bituminous coal as transport air and coal flow distribution was varied from a condition of relative imbalance to a condition of relative balance as indicated by individual meter coal flow rates. In order to validate the experimental results, and verify the performance of the meters, a calibration experiment was initiated in March using a barrel with a bag filter connected to each of the 12 BSF coal lines to allow the individual coal flow rates to be determined by the barrel weight.

During this work a series of 5 barrel tests were performed to verify the operation of the coal mass flow meters and resultant combustion test conditions. For this work coal was fed for approximately 15-20 minutes for each test at rates ranging from 3,000 to 5,000 lb/hr (re. up to and beyond the nominal week 1 combustion test feed rate of 4,400 lb/hr). Upon completion of each test, the barrels were weighed and the output from the mass flow meters (mass flow rate) was integrated to allow comparison between the actual and the meter indicated amount of coal. The coal flow distribution as measured by the barrel weights is shown in Figure 1. As illustrated in the figure, the tests are fairly repeatable and, with the exception of a couple of the barrels, there is generally little variation in the distribution as a function of feed rate.

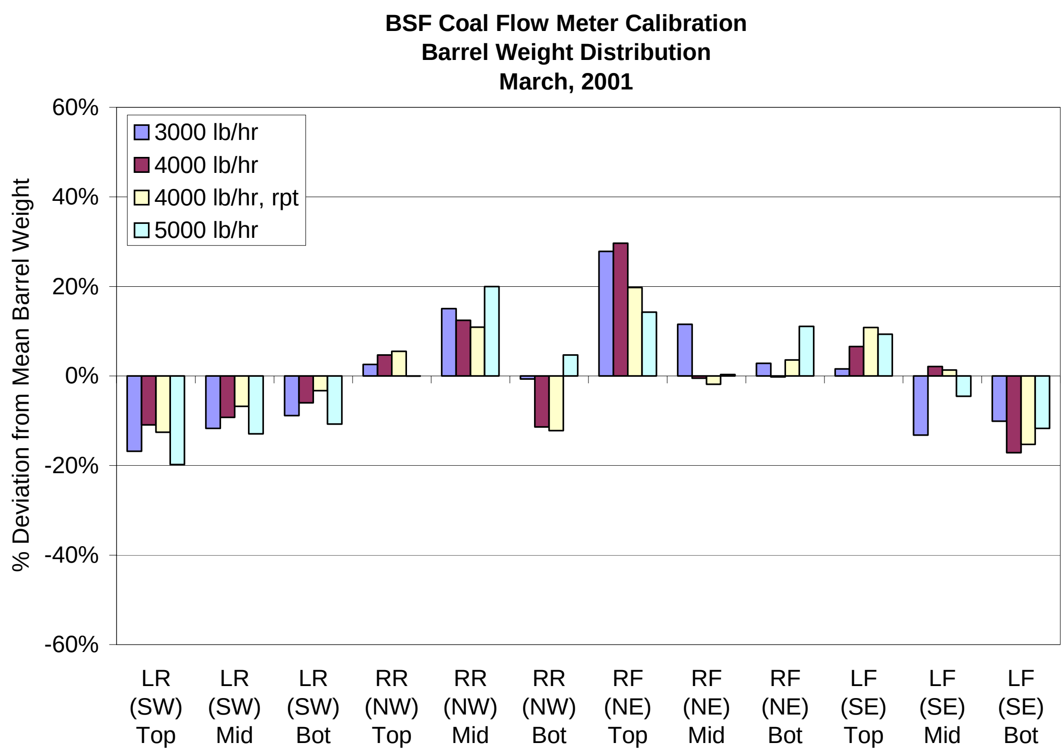

Figure 1. Deviation in barrel weights as a function of coal feed rate.

The error in the coal flow meter measurements for the same set of tests is shown in Figure 2. As shown in the figure, the maximum error in the coal flow meter measurements was over 40% with the average error being 23%. The testing showed poor agreement between most of the coal mass flow meter measurements and the barrel weights. Subsequent to this finding the vendor (ABB Kent-Taylor) was notified of this problem. They then executed their own test campaign with some flow meters that were produced in the same batch as those installed on the BSF and proposed a solution that involved both hardware and software changes.

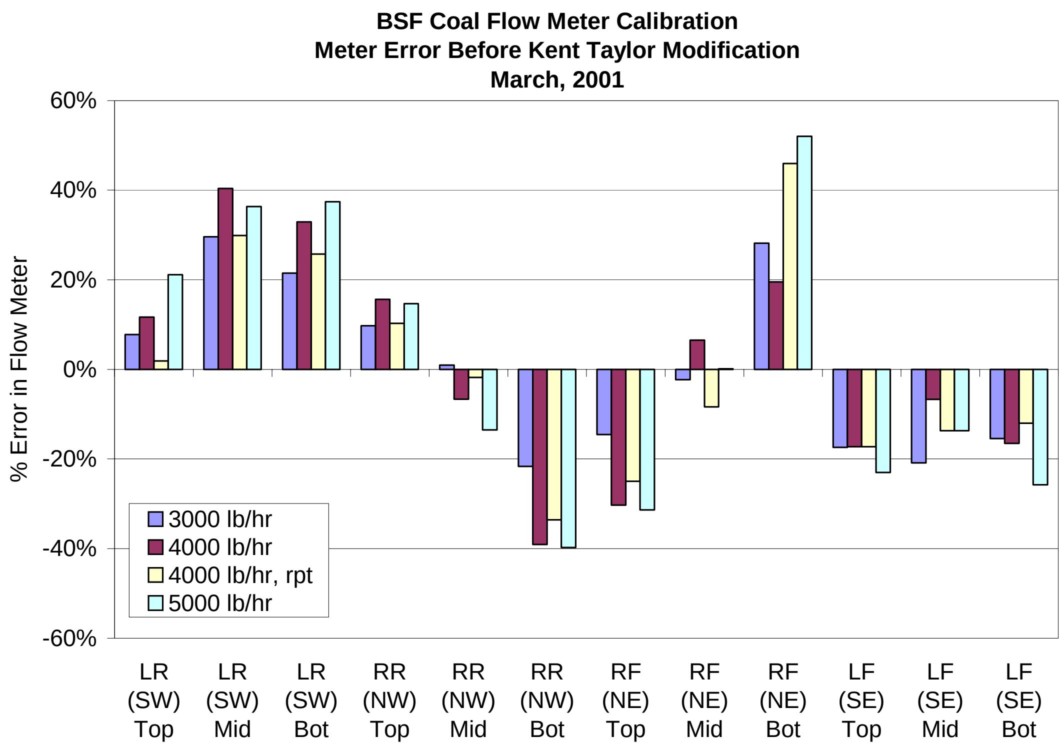

Figure 2. Error in coal flow meters as a function of coal feed rate.

ABB Kent Taylor personnel were at the Windsor site in April to implement their proposed solutions and to examine the installed system. Both hardware and software changes were made to the coal flow meter system. However, additional barrel tests performed after the system was modified showed no improvement in the relative accuracy of the coal flow meters. As illustrated in Figure 3, the magnitude of the error in the coal flow meters increased after the modifications. In addition, some of the coal flow meters that were measuring higher than the barrel weights before the modification were now reading lower and vice versa.

An attempt to add calibration factors to correct the mass flow meters was also unsuccessful as shown in Figure 4. The use of the calibration factor did not significantly improve the average error in the meter, with some of the meters having errors larger than 40%. At this point it was decided that there was no easy fix for the mass flow meters and the BSF testing would proceed without them.

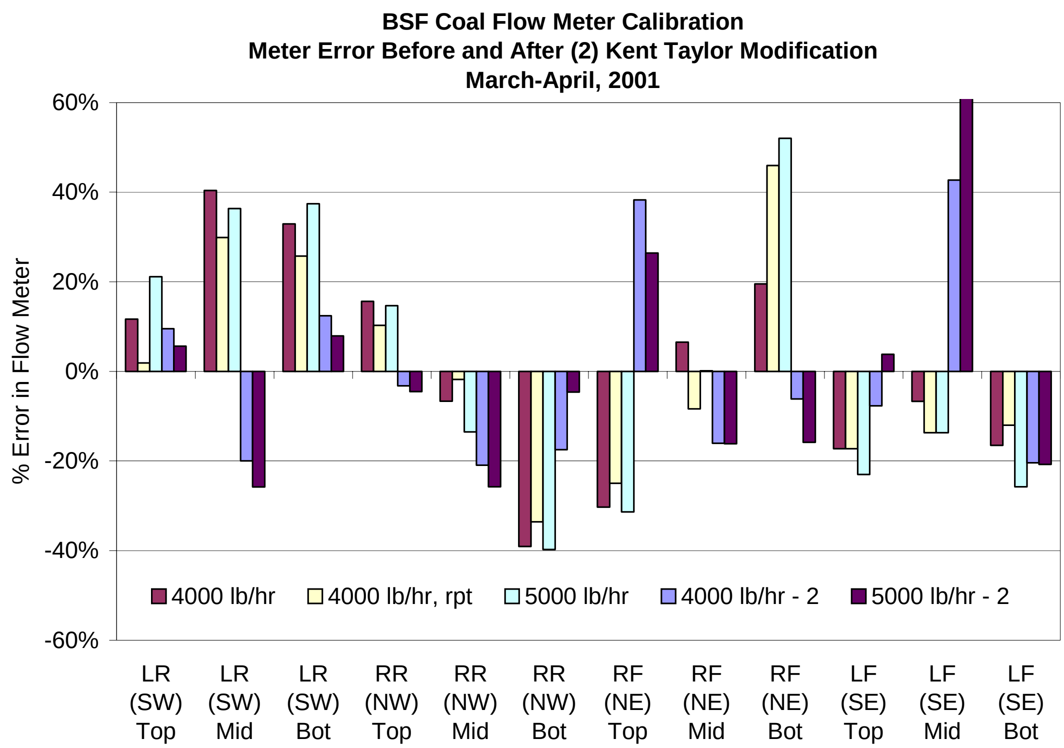

Figure 3. Error in coal flow meters as a function of coal feed rate before and after Kent Taylor modification. After tests are indicated by –2 in the legend.

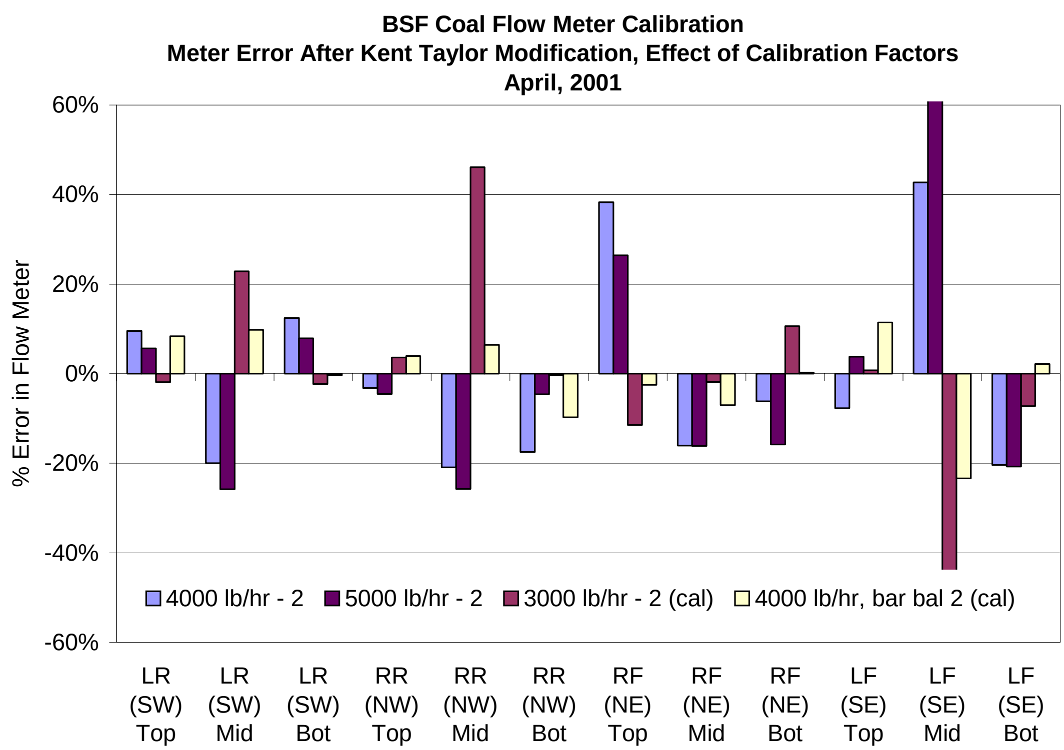

Figure 4. Error in coal flow meters as a function of coal feed rate after Kent Taylor modification with calibration factors applied (cal).

- *Additional instrumentation and measurement equipment tested in BSF week 2.*

Three new instruments were included in the diagnostic measurements made during the second phase of testing in the BSF:

1) Acoustic pyrometry
2) Single point flame sensing (advanced flame scanner)
3) 2-D flame imaging.

1) Acoustic pyrometer.

The first innovative instrument utilized during the test program was an acoustic pyrometer to provide only, continuous measurement of the furnace outlet temperature (FOT). Supplied by Scientific Engineering Instruments (SEI) of Reno Nevada, the acoustic pyrometer provided an average temperature in the furnace at the horizontal furnace outlet plane (BSF nose). During BSF testing, a 2-transceiver system was used where the transceivers were mounted externally on 6 inch sample ports that were directly across from each other. The acoustic pyrometer provided the average (line of sight) temperature across the BSF which was transmitted into the DCS system and recorded as a function of time with the other operating variables.

Good agreement between the SEI instrument and the expected trends in furnace temperature as a function of operating conditions (i.e., excess air, amount of overfire air, boiler load, etc.) was observed during the testing. The magnitude of the FOT measured by the SEI instrument was somewhat lower than that measured by suction pyrometry, but may be a result of the correction factors used to “calibrate” the pyrometer. As the line of sight measurement passes through the relatively cool gases in the BSF sample ports (due to the cooling effects of the water jacket), a correction to the signal must be made to eliminate the attenuation caused by the cool gas. In spite of the “calibration” issues, the acoustic pyrometer system provided a reasonably accurate indication of changes in the furnace outlet temperature over the course of the testing.

2) Single Point Flame Sensing

Two traditional “off-on” flame scanners were installed in the main burner zone of the furnace. Unlike a standard installation, these sensors were located perpendicular to the flame axis. Both ultra-violet and visible light scanners were used to monitor the flame front during the test matrix including variation to the local and global stoichiometry. Scanner outputs were recorded and this data will be evaluated to determine whether detector signal to furnace condition correlations can be quantified.

3) 2-D Flame Imaging

Lastly, a pair of CCD cameras were used to make short digital flame video clips. The cameras recorded the flame image at over a dozen test conditions, including variations in global stoichiometry. Similar to the flame scanner data, the 2D flame images will be processed to establish flame features which will then be correlated with furnace operating parameters. The objective with both of these two later instruments is the inference of furnace operating conditions through the application of flame monitoring optical methods for online optimization and automated control.

Task 3.1 – Test Planning & Facility Preparation

- *Complete preparations for week 2 BSF testing*.

All mechanical and electrical repairs were made to the BSF and the DCS system to allow execution of the second combustion test period during the week of April 29, 2001.

Task 3.3 – Combustion Testing and Cleanup

- *Complete the second combustion test period in the BSF.*

The second combustion test period in the BSF was executed 4-30-01 through 5-5-01. During this testing two coals were fired in the BSF, a subbituminous coal from the Powder River Basin (Cordero Rojo Complex Coal, Kennecott Energy) and a high volatile bituminous coal from Southern Indiana. The as fired (after pulverization) coal compositions are shown in Table 1.

Table 1. BSF Test Coal Analyses, as Fired.

	Test Week 1	**Test Week 2**	**Test Week 2**
	Pulverized	**Pulverized**	**Pulverized**
			Cordero Rojo
	Med Vol Bit	**High Vol Bit**	**Sub Bit**
Proximate			
VM	22.5%	37.7%	35.6%
FC	63.1%	51.4%	39.6%
FC/VM	2.8	1.4	1.1
VM, DAF	26.3%	42.6%	47.3%
Ultimate			
Moisture	0.9%	4.3%	18.9%
Hydrogen	4.0%	4.9%	3.7%
Carbon	74.7%	71.6%	56.4%
Sulfur	1.4%	2.5%	40.0%
Nitrogen	1.3%	1.5%	90.0%
Oxygen	4.2%	7.9%	13.8%
Ash	13.6%	7.2%	5.9%
Total	100.0%	100.0%	228.7%
HHV, BTU/lb	13,109	13,088	9,890
O/N	3.2	5.3	0.2
lb N/MMBTU	0.99	1.15	91.00
lb S/MMBTU	1.04	1.91	40.44
lb Ash/MMBTU	10.3	5.5	6.0

During the second combustion test week the following variables were examined:

1. MBZ Stoichiometry
2. Staged Residence Time
3. Near Field Stoichiometry
   a. Transport air to fuel ratio
   b. Fuel air flow
   c. Subcompartmentalization
4. Transport Air & Fuel Flow Balancing
   a. Coal flow balancing
   b. Vertical coal bias (top coal%)
5. SOFA Elevation (1 vs. 2)
6. SOFA Velocity (field equivalent)

7. Boiler Load
8. Coal Fineness (sub-bit coal)
9. Excess Air (USOFA flow variation)
10. Bottom End Air
    a. Quantity
    b. Location
11. Coal Ballistics
    a. Low-set / compressed WB
    b. Coal yaw / tilt

Approximately 80 test were run on the subbituminous coal and 35 on the high volatile bituminous coal. At each test condition, approximately 30 minutes of gaseous emissions data including O_2, CO, CO_2, SO_2 and NOx was collected along with high volume fly ash samples.

Preliminary results from the testing indicate a baseline (re. unstaged / post-NSPS type) NOx emission level of approximately 0.50 lb/MMBtu for the subbituminous coal and 0.60 lb/MMBtu for the bituminous coal. At optimized conditions, NOx emissions values significantly below the test objectives of 0.10 lb/MMBtu for the subbituminous coal and 0.15 lb/MMBtu for the bituminous coal were achieved during the testing with low levels of CO and unburned carbon. Further results from the BSF testing will be presented in the May monthly report after the data reduction process has proceeded to a point where test conditions and results have been verified.

A photo of ALSTOM Power's Boiler Simulation Facility (BSF) in operation during the 2nd combustion test period is given in Figure 5. A picture of a coal flame taken through a view port in the BSF when firing the PRB coal under staged conditions is shown in Figure 6.

Figure 5. Photo of ALSTOM Power's Boiler Simulation Facility (BSF) in operation during the 2nd combustion test period.

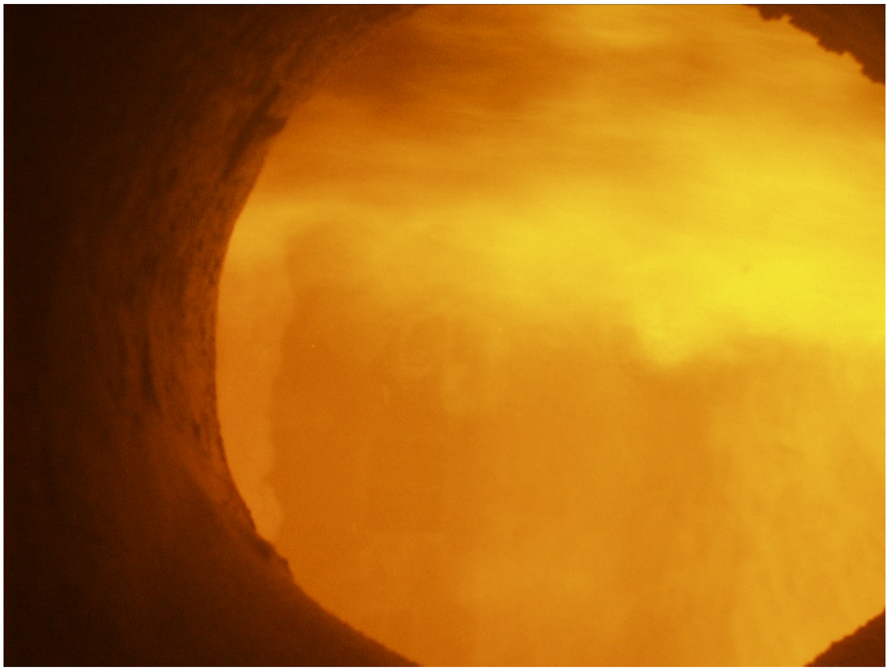

Figure 6. Photo of staged PRB flame ALSTOM Power's Boiler Simulation Facility (BSF).

WORK PLANNED FOR NEXT REPORTING PERIOD:

Task 2.4 – Advanced Control System Design

- Begin analysis of the flame scanner data.

Task 3.3 – Combustion Testing and Cleanup

- Begin cleanup from the second combustion test period in the BSF.

Task 3.5 – Data Reduction and Analysis

- Begin data reduction and analysis from second combustion test period.

Task 8 – Project Management

- Come to closure on the modified statement of work provided to DOE in Feb. 2001.